

IN THE CLAIMS

Claim 1 (Currently Amended) An attenuating phase shift mask blank for use in lithography comprising:

substrate;

a phase shifting layer disposed on said substrate;

said phase shifting layer comprising a top surface layer rich in oxygen;

said top surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

said phase shift mask blank is capable of producing a photomask with substantially 180° phase shift and an optical transmission of at least 0.001% at a selected wavelength of <500nm.

Claim 2 (Original) An attenuated phase shift mask blank according to claim 1 wherein the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$, where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7.

Claim 3 (Original) An attenuated phase shift mask blank according to claim 1 wherein the phase shifting layer comprises a material selected from the group consisting of a silicon/ titanium/nitrogen composite and a silicon/titanium/nitrogen/oxygen composite.

Claim 4 (Original) An attenuated phase shift mask blank according to claim 3 wherein said silicon/titanium/nitrogen composite has structural formula $\text{Si}_w\text{Ti}_x\text{N}_y$, wherein $w = 0.1\sim 0.6$, $x = 0.01\sim 0.2$, $y = 0.3\sim 0.6$.

Claim 5 (Original) An attenuating phase shift mask blank according to claim 3 wherein said silicon/titanium/nitrogen/oxygen composite has structural formula $\text{Si}_w\text{Ti}_x\text{N}_y\text{O}_z$, wherein $w = 0.1\sim 0.6$, $x = 0.01\sim 0.2$, $y = 0\sim 0.6$, and $z = 0\sim 0.7$.

Claim 6 (Original) An attenuating phase shift mask blank according to claim 1, wherein the phase shifting layer has a thickness of from about 400 Å to about 2000 Å wherein said surface layer rich in oxygen has a thickness of from about 10 Å to about 150 Å.

Claim 7 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said phase shifting layer comprises a top surface layer;

said top surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelength of <500nm.

Claim 8 (Original) A method according to claim 7 wherein the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$, where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7.

Claim 9 (Original) A method according to claim 7 wherein the phase shifting layer comprises a material selected from the group consisting of a silicon/titanium/nitrogen composite and a silicon/titanium/nitrogen/oxygen composite.

Claim 10 (Currently Amended) A method according to claim 9 wherein said silicon/titanium/nitrogen composite has structural formula $Si_wTi_xN_y$, wherein $w = 0.1\sim0.6$, $x = 0.01\sim0.2$, $y = 0.3\sim0.6$, $y/[z] = 0\sim0.7$.

Claim 11 (Original) A method according to claim 9 wherein said silicon/titanium/nitrogen/oxygen composite has structural formula $Si_wTi_xN_yO_z$ wherein $w = 0.1\sim0.6$, $x = 0.01\sim0.2$, $y = 0\sim0.6$, and $z=0\sim0.7$.

Claim 12 (Original) A method according to claim 7 wherein the phase shifting layer is formed by sputter deposition from a target of a composite material ($Si_{1-x}Ti_x$) wherein $x=0.01\sim0.5$ by a method selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

Claim 13 (Original) A method according to claim 12 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

Claim 14 (Original) A method according to claim 8 wherein the phase shifting layer is formed by sputter deposition from a target of a composite material ($\text{Si}_{1-x}\text{Ti}_x$) wherein $x=0.01\sim 0.5$ by a method selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

Claim 15 (Original) A method according to claim 14 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

Claim 16 (Original) A method according to claim 9 wherein the phase shifting layer is formed by sputter deposition from a target of a composite material ($\text{Si}_{1-x}\text{Ti}_x$) wherein $x=0.01\sim 0.5$ by a method selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

Claim 17 (Original) A method according to claim 16 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

Claim 18 (Original) A method according to claim 7 wherein the phase shifting layer is formed by sputter deposition from two or more targets of different compositions using a technique selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

Claim 19 (Original) A method according to claim 18 wherein said two or more targets are selected from the group consisting of Si_3N_4 and Ti targets, or ($\text{Si}_{1-x}\text{Ti}_x$) wherein $x=0.01\sim 0.5$ and Ti targets.

Claim 20 (Original) A method according to claim 18 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

Claim 21 (Original) A method according to claim 8 wherein the phase shifting film is formed by sputter deposition from two or more targets of different compositions using a technique selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron and RF diode.

Claim 22 (Original) A method according to claim 21 wherein said two or more targets are selected from the group consisting of Si_3N_4 and Ti targets, or $(\text{Si}_{1-x}\text{Ti}_x)$ wherein $x=0.01\sim0.5$ and Ti targets.

Claim 23 (Original) A method according to claim 21 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

Claim 24 (Original) A method according to claim 9 wherein the phase shifting layer is formed by sputter deposition from two or more targets of different compositions using a technique selected from the group consisting of RF matching network, DC magnetron, AC magnetron, pulsed bipolar DC magnetron or RF diode.

Claim 25 (Original) A method according to claim 24 wherein said two or more targets are selected from the group consisting of Si_3N_4 and Ti targets, or $(\text{Si}_{1-x}\text{Ti}_x)$ wherein $x=0.01\sim0.5$ and Ti targets.

Claim 26 (Original) A method according to claim 24 wherein the substrate is disposed in a holder which can be either planetary or stationary and/or rotating or non-rotating.

Claim 27 (Original) A method according to claim 7 wherein structural changes occur in said phase shifting layer to stabilize against radiation and chemical treatment by including an increased surface oxygen concentration to form said surface layer rich in oxygen which is obtained by annealing at elevated temperature in an atmosphere selected from the group consisting of air, oxygen, vacuum and a mixture of gases selected from the group consisting of O_2 , N_2 , H_2 , Ar, Kr, Ne, He, O_3 and H_2O .

Claim 28 (Original) A method according to claim 8 wherein structural changes occur in said phase shifting layer to stabilize against radiation and chemical treatment by including an increased surface oxygen concentration to form said surface layer rich in oxygen which is obtained by annealing at elevated temperature in an atmosphere selected from the group consisting of air, oxygen, vacuum and a mixture of gases selected from the group consisting of O₂, N₂, H₂, Ar, Kr, Ne, He, O₃ and H₂O.

Claim 29 (Original) A method according to claim 9 wherein structural changes occur in said phase shifting layer to stabilize against radiation and chemical treatment by including an increased surface oxygen concentration to form said surface layer rich in oxygen which is obtained by annealing at elevated temperature in an atmosphere selected from the group consisting of air, oxygen, vacuum and a mixture of gases selected from the group consisting of O₂, N₂, H₂, Ar, Kr, Ne, He, O₃ and H₂O.

Claim 30 (Original) A method according to claim 7 wherein the annealing can be done by using methods selected from the group consisting of laser annealing, plasma annealing, thermal annealing, microwave annealing and radiation treatment.

Claim 31 (Original) A method according to claim 8 wherein the annealing can be done by using methods selected from the group consisting of laser annealing, plasma annealing, thermal annealing, microwave annealing and radiation treatment.

Claim 32 (Original) A method according to claim 9 wherein the annealing can be done by using methods selected from the group consisting of laser annealing, plasma annealing, thermal annealing, microwave annealing and radiation treatment.

Claim 33 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelenth of <500nm;

~~A method according to claim 7 wherein the surface layer rich in oxygen is obtained by oxygen plasma bombardment.~~

Claim 34 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelength of <500nm:

the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$ where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7;

~~A method according to claim 8 wherein the surface layer rich in oxygen is obtained by oxygen plasma bombardment.~~

Claim 35 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelength of <500nm:

the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$ where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7;

the phase shifting layer comprises a material selected from the group consisting of a silicon/titanium/nitrogen composite and a silicon/titanium/nitrogen/oxygen composite;

A method according to claim 9 wherein the surface layer rich in oxygen is obtained by oxygen plasma bombardment.

Claim 36 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelength of <500nm;

~~A method according to claim 7 wherein an oxygen partial pressure of the process gas during deposition is increased at the final stage of deposition.~~

Claim 37 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelength of <500nm;

the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$, where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7;

~~A method according to claim 8 wherein an oxygen partial pressure of the process gas during deposition is increased at the final stage of deposition.~~

Claim 38 (Currently Amended) A method of fabricating an attenuating phase shift mask blank for use in lithography comprising:

providing a substrate;

disposing a thin layer of phase shifting layer on said substrate;

said surface layer comprises a higher concentration of oxygen than that part of said phase shifting layer not including said surface layer;

forming a surface layer rich in oxygen on said phase shifting layer;

wherein said blank is capable of producing a photomask with 180° phase shift and an optical transmission of at least 0.001 % at a selected wavelength of <500nm;

the phase shifting layer comprises a composite material of formula $A_wB_xN_yO_z$, where A is an element selected from the group consisting of Groups IVA, VA, or VIA; and B is selected from the group consisting of an element from Groups II, IV, V, the transition metals, the lanthanides and the actinides; wherein w is in a range between 0.1 and 0.6, x is in a range between 0.01 and 0.2, y is in a range between 0 and 0.6, and z is in a range between 0 and 0.7;

the phase shifting layer comprises a material selected from the group consisting of a silicon/titanium/nitrogen composite and a silicon/titanium/nitrogen/oxygen composite;

~~A method according to claim 9 wherein an oxygen partial pressure of the process gas during deposition is increased at the final stage of deposition.~~

Claim 39 (Original) A method according to claim 7 wherein the sputter target is made by hot isostatic pressing. .

Claim 40 (Original) A method according to claim 8 wherein the sputter target is made by hot isostatic pressing.

Claim 41 (Original) A method according to claim 9 wherein the sputter target is made by hot isostatic pressing.

Claim 42 (Original) A method according to claim 7 wherein the sputter target is made of a mixture of metal silicide and silicon.

Claim 43 (Original) A method according to claim 8 wherein the sputter target is made of a mixture of metal silicide and silicon.

Claim 44 (Original) A method according to claim 9 wherein the sputter target is made of a mixture of metal silicide and silicon.

Claim 45 (Original) A method according to claim 7 wherein the sputter target is made of a mixture of titanium silicide and silicon.

Claim 46 (Original) A method according to claim 8 wherein the sputter target is made of a mixture of titanium silicide and silicon.

Claim 47 (Original) A method according to claim 9 wherein the sputter target is made of a mixture of titanium silicide and silicon.